

PRESENT TRENDS OF BIOFUEL PRODUCTION AND CONSUMPTION IN THE EUROPEAN UNION

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Abstract

Biofuel is one of the trending research areas in the production and consumption economy. Based on the significance of biofuels, this study specifies the objective to explore and discuss the present trends of biofuel production and consumption in European Union listed countries. A descriptive data analysis technique is conducted here using the data from the BP Statistical Review of World Energy, European Union energy annuals, RES Barometer, and STATISTA databases. This study finds that among the 27 EU countries, Austria, Belgium, Bulgaria, Finland, France, Germany, Hungary, Italy, Netherlands, Poland, Portugal, Spain, and Sweden are highly concerned regarding biofuel production and consumption. Due to the unavailability of balanced yearly data, different years' data are used here to conduct the descriptive analysis. Germany and France are in the leading position in biofuel economic circumstances, particularly from both biofuel production and consumption perspective. It is also found that sugar beets, corn, and wheat are the most used feedstock used for biofuel production, and transportation is the largest source of biofuel consumption.

Keywords: *biofuel production, biofuel consumption, biodiesel, biofuels*

JEL code: *Q20, Q42, Q43, Q57*

A BIOÜZEMANYAG-TERMELÉS ÉS -FOGYASZTÁS JELENLEGI HELYZETE AZ EURÓPAI UNIÓBAN

Összefoglalás

A bioüzemanyag a megújuló energia termelése és -fogyasztása fontos kutatási területe. A kutatás célkitűzése, hogy feltárja a bioüzemanyag-termelés és -fogyasztás jelenlegi trendjeit az Európai Unióban. A módszertan alapja az adatelemzési technika a BP Statistical Review of World Energy, a Nemzetközi Energia Ügynökség, az Egyesült Államok Energia Információs Hivatala (EIA), az Európai Unió éves energiaszolgáltatásai, a RES Barometer és a STATISTA adatbázisok adatainak felhasználásával. Megállapítottuk, hogy a EU27 közül Ausztria, Belgium, Bulgária, Finnország, Franciaország, Németország, Magyarország, Olaszország, Hollandia, Lengyelország, Portugália, Spanyolország és Svédország bioüzemanyag-termelése és -fogyasztása jócskán elmarad a vezető tagországok mögött. Németország és Franciaország vezet a bioüzemanyag felhasználásban. Azt is megállapítottuk, hogy a cukorrépa, a kukorica és a búza a bioüzemanyag-előállítás leggyakrabban használt alapanyaga, a közlekedés pedig magasan vezet a bioüzemanyag-fogyasztásban.

Kulcsszavak: *bioüzemanyagtermelés, bioüzemanyag fogyasztás, biodízel, bioethanol*

Introduction

The term "biofuel" refers to fuel ethanol and biodiesel made from biological resources, liquid or biomass. These can replace gasoline and diesel made from petroleum and are key steps in developing and using renewable energy (HOU et al., 2022). The widespread consensus is that biofuels offer a wide range of benefits, including supply security, regional development, social structure and agriculture, sustainability, and the reduction of greenhouse gas emissions (OLÁH & POPP, 2022). Since the 1970s, several nations have devoted growing attention to developing biofuels and have seen impressive results, influenced by the world's oil supply, prices, environmental protection, and global climate change. The development of biofuels in the EU has also made significant developments since the 1990s, particularly with manufacturing fuel ethanol from grain. The biofuel technologies are categorized into first, second and third generation depending on the type of biomass used and the production processes adopted (MATHIJS et al., 2015). The two most popular biofuels, biodiesel and ethanol, are preferable to fossil fuels but fall short of society's energy needs (CADILLO-BENALCAZAR et al., 2021).

This uncertainty has prompted the automobile industry to convert to oil-free electric vehicles, further upsetting oil demand (KAH, 2018). As the COVID-19 epidemic has negatively affected numerous industries in the EU, it has also been demonstrated to severely impact the biodiesel industry (HALIMATUSSADIAH et al., 2021; MIZIK et al., 2020; VEZA et al., 2021). Due to disturbances in the supply chain and distribution, as well as a decrease in feedstock production, the biodiesel industry has been put under immense pressure by the precipitous decline in fuel demand (ELLEBY et al., 2020; HARSÁNYI et al., 2021; MOHAMMED et al., 2020). This is because fewer people are dining out due to the epidemic, decreasing maize oil demand and production.

A typical argument against biofuels, particularly ethanol, is that their production uses more energy than they produce. In truth, biofuels require significantly more energy to create than fossil fuels, which is less than the energy they generate. According to the US Department of Energy, corn-based ethanol produces at least 30% more energy than it requires to generate (1). Considering environmental and agricultural debates, the next-generation biofuels market becomes increasingly important – particularly if they can solve waste management problems and use the traditional infrastructure (biomethane, used cooking oil) (BAI, 2011). Public awareness could also be assessed as a crucial factor in present and future use; according to SZAKÁLY et al. (2021), around one-third of the Hungarian residents did not hear about biodiesel and bioethanol, and another one third have just basic knowledge.

Considering the above circumstances and other global issues, there have been significant changes in biofuel production and consumption in the EU. With this in mind, the specific objective of this study is to explore the main trends in the production and consumption of biofuels in EU countries. More specifically, this study extends to understanding EU overall biofuel and fuel ethanol production trends, EU country-specific biofuel and fuel ethanol production, specific fuel ethanol feedstock consumption, country-specific biofuel and fuel ethanol consumption, and usage prospects renewable energy consumption. To accomplish the objectives of this study, a descriptive data analysis is conducted. The results are presented using multiple figures and tables. The findings of this study include the biofuel and bioethanol production and consumption trends in the EU and specific countries. Also, the share of biofuel usage and consumption of biodiesel for transportation is specified in the findings section.

This study is presented in a structured way. The first section presents the introduction, the second section presents the methodology, the third section is the finding, and the fourth section is the discussion and conclusion. In conclusion, the scope of this research is the emerging trends of biofuel production and consumption in the EU region.

Methodology

The purpose of this research is to present the current situation in biofuel production and consumption in EU countries. The step-by-step methodological process is mentioned in the following section.

Biofuel is one of the trending research areas in the production and consumption economy. Some renowned energy databases provide most of the energy economics data. We collect the data from *BP Statistical Review of World Energy*, *European Union energy annuals*, *RES Barometer*, and *STATISTA databases*. Different periods of data are collected for this study. For example, biofuel production trends (2000 to 2021), country-specific biofuel production data (specific countries per day biofuel oil production), fuel ethanol production (2012 to 2021), leading biofuel consumer data (2020 and 2021), fuel ethanol feedstock consumption data (2012 to 2021), country-specific fuel ethanol consumption (2020 and 2021), biofuels consumption for transport (2015 to 2020).

The research area is specified the European Union. Mainly 27 EU countries' data are used in this study. In turn all countries are not enriched with biofuel production technologies. Therefore, not all European countries significantly produce biofuels. Only the highlighted results are presented here. More particularly, the country-specific analysis is done based on data from Austria, Belgium, Bulgaria, Finland, France, Germany, Hungary, Italy, Netherlands, Poland, Portugal, Spain, and Sweden.

This study conducts descriptive data analysis techniques, such as figure description, chart description, comparison, table comparison, and so other, to experiment with the results. In most cases, figures and tables are used to describe results. The specific data measure is also presented in each table and figure.

Findings

The study findings include biofuel production trends, country-specific biofuel production in Europe, fuel ethanol production in the EU, leading fuel ethanol producers, fuel ethanol feedstock consumption, country-specific fuel ethanol consumption, share most used renewable energy consumption, and biofuel consumption for transport. The findings of this study are presented specifically in the following sections.

Biofuel production trends in the EU

The EU is the global leader in biodiesel production and its use in transportation. It is among Europe's most widely used biofuel, with annual consumption exceeding 14 million tonnes. Biodiesel produced in Europe reduces the demand for fossil diesel imports, contributes significantly to the development of the circular and bioeconomy, reduces the demand for imported animal feed, and strengthens the rural economy. The European biodiesel industry is directly responsible for creating 25,000 jobs out of 220,000 in the EU biofuels industry (2). According to the *BP STATISTICAL REVIEW OF WORLD ENERGY* report (2021), the EU produced approximately 236 thousand barrels of oil equivalent per day, a decrease of 2,000 barrels per day compared to the previous year, 2020. The year-by-year (2000 to 2021) biofuel production trends in the EU are mentioned in the following Figure 1. Due to the COVID-19 pandemic's demand shock and the initial round of lockdown measures put in place by countries to combat their biofuel markets (DUTTA et al., 2021; MIZIK et al., 2020). In 2020, due to COVID-19, there was an abrupt slowdown in economic growth. The year 2020 sees a sharp decline in the price of biofuels, followed by a decline in the price of their primary feedstocks,

maize and oilseeds. Although the epidemic has likely increased food insecurity in many developing nations due to income losses and local supply chain disruptions. Global food consumption is mostly unaffected because of the inelastic demand for most agricultural commodities and the brief duration of the shock (ELLEBY et al., 2020, OLÁH, 2022). However, between 2000 and 2021, the number increased by 224 thousand barrels of oil equivalent per day, reaching a peak of 243 thousand barrels of oil equivalent per day in 2019.

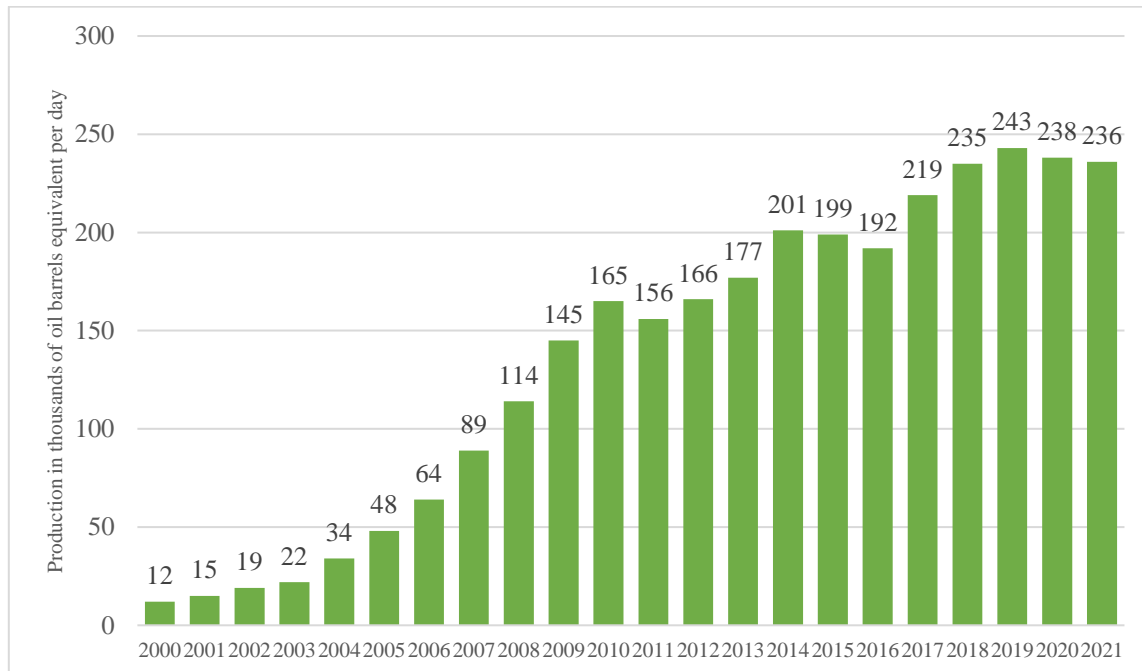


Figure 1. Biofuel production trends in the EU (2000-2021)

Source: Author illustration

Country-specific biofuel production in Europe

Since the turn of the century, the total production of biofuels in the EU has increased dramatically. The total production reached 236 thousand barrels of oil equivalent per day in 2021 (Figure 1). Germany produced the most biofuels in Europe in 2021, equivalent to 54 thousand barrels of oil per day. It was 6 thousand barrels of oil equivalent per day higher than France, which produced the second-most that year. This is lower than the previous years. For example, according to *BP Statistical Review of World Energy*, the per day biofuel production in Germany was 63 thousand barrels in 2020, 66 thousand barrels in 2019, 63 thousand barrels in 2018, 61 thousand barrels in 2017, 60 thousand barrels in 2016, and 59 thousand barrels in 2015. In Germany, between 2000 and 2021, daily production increased by 50,000 barrels of oil equivalent. As of 2021, the production accounted for 3.4% of global biofuel production. The details of country-specific biofuel production information are mentioned in Figure 2. In 2021, biofuel production in France reached 48 thousand barrels of oil equivalent per day, a 12 per cent increase from the previous year. During the period under review, the numbers increased by 42 thousand barrels of oil equivalent per day, reaching a peak of 50 thousand barrels of oil equivalent per day in 2021. Most of these biofuels (60 %) have been produced from eligible wastes and residues. Netherlands, Spain, and Italy are in the 3rd, 4th, and 5th ranked in the top daily biofuel producer country list with 38, 32, and 21 thousand barrels per day, respectively. The other countries with daily biofuel production are Poland (19), Sweden (11), Belgium (9), Austria (8), Finland (5), and Portugal (5).

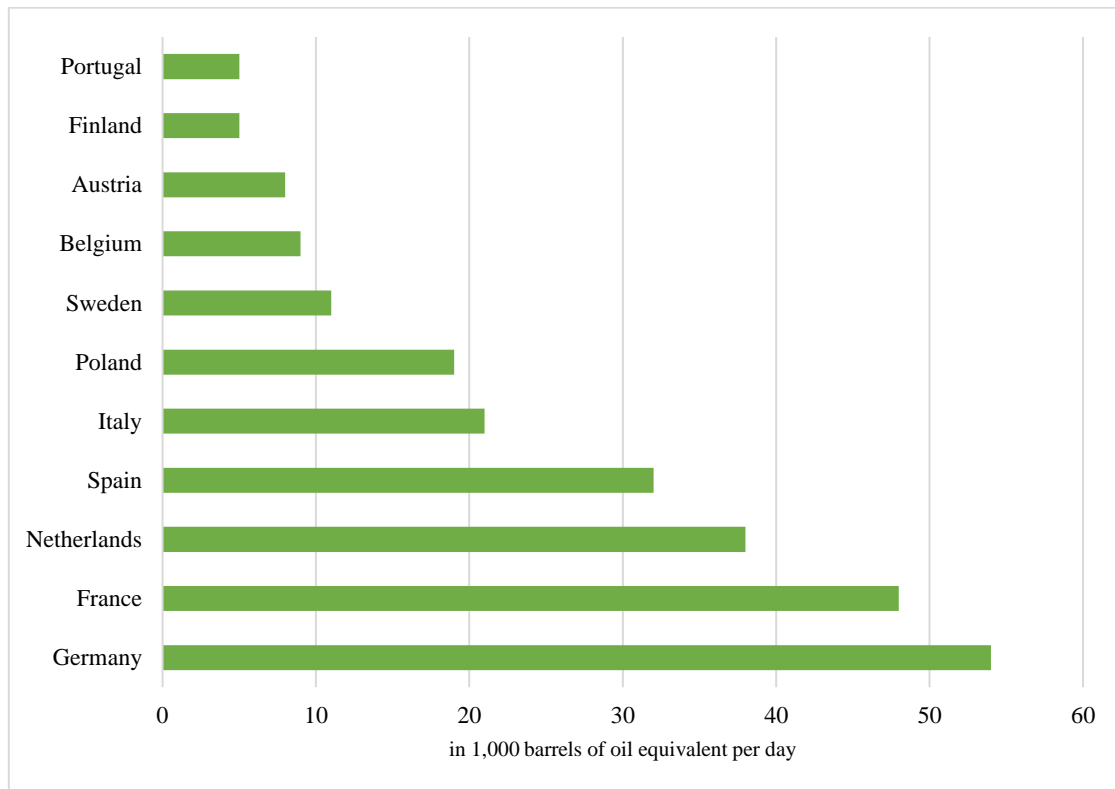


Figure 2. Country-specific biofuel production in Europe (2021)

Source: Author illustration

Fuel ethanol production in the EU:

Bioethanol contains significantly less energy than gasoline (about two-thirds of the energy content of the latter on a volume base) (CHAKRABORTY & MUKHOPADHYAY, 2020; KUNAMALLA et al., 2021). This implies that, for mobility applications, for a given tank volume, the vehicle's range is diminished proportionally. The octane number of ethanol is greater than that of gasoline; therefore, ethanol has superior antiknock properties. This improved fuel quality can be utilised by adjusting the compression ratio of the engine accordingly. This improves the engine's fuel efficiency. Ethanol's oxygen content also improves efficiency, resulting in a cleaner combustion process at relatively low temperatures (3). According to *European Union Biofuels Annual (2021)*, the EU was projected to produce approximately 5.6 billion litres of fuel ethanol. This would represent an increase of nearly three per cent over the previous year. During the period under consideration, 2018 saw a peak of 6,1 billion litres. The EU's ethanol production decreased in 2020, most likely because of reduced mobility caused by lockdown measures during the COVID-19 pandemic (MIZIK et al., 2020). The details of fuel ethanol production in the EU information are mentioned in Figure 3.

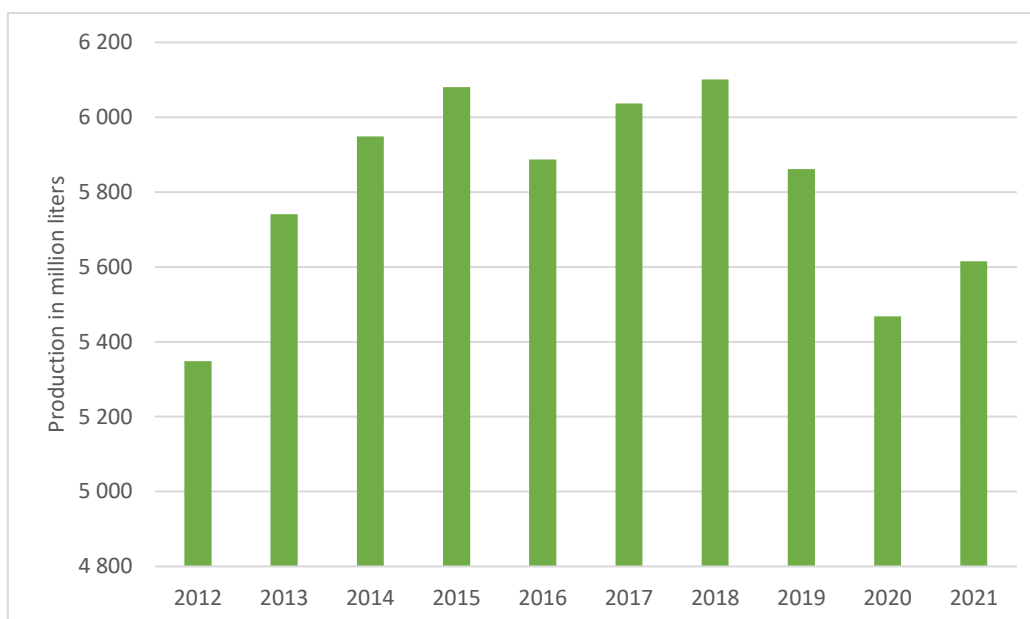


Figure 3. Fuel ethanol production in the EU (2012-2021)

Source: Author illustration

Leading producers of fuel ethanol

The European Union's largest producer of fuel ethanol is France. According to European Union Biofuels Annual, in 2021, the nation's production was projected to reach nearly 1.1 billion litres, up 4.4% from the previous year. In comparison, Germany's ethanol production in 2021 was anticipated to reach 950 million litres. Hungary's ethanol production in 2021 was anticipated to reach 640 million litres. Hungary is the third largest consumer of ethanol in the European Union, while the Netherlands ranks fourth with 570 litres. There are no significant changes in Hungary's ethanol production compared to 2021. In 2021, Spain ranked fifth with 480 litres, which is lower than in 2020. The details information on leading fuel ethanol producers is given in Figure 4.

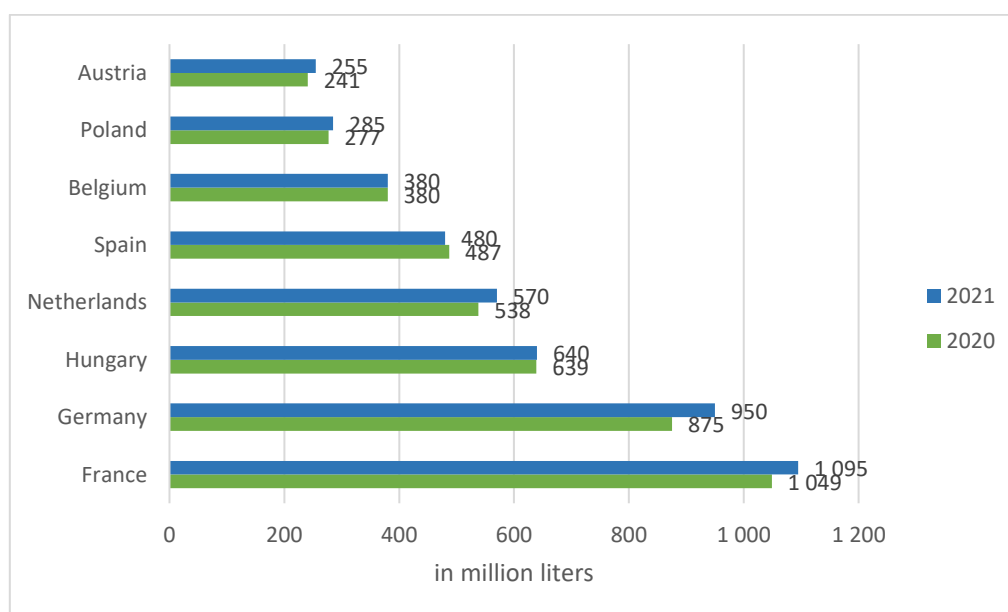


Figure 4. Leading producers of fuel ethanol in the EU (2020-2021)

Source: Author illustration

Fuel ethanol feedstock consumption

The details of the feedstock consumption scenario are given in Table 1. Although corn, molasses, and sugar cane are the world's main sources of bioethanol production, other starchy materials like wheat, barley, and rye are also appropriate. Starch-containing crops must first be transformed into sugars. For the manufacturing of 1 tonne of ethanol, approximately 3 tonnes of grains are required as the feedstock. Starch crops (such as ordinary wheat) and sugar beets are the main crops used in Europe to produce bioethanol. Most of the EU-25 nations grow sugar beetroot crops, which produce a lot more ethanol per hectare than wheat (4). In the EU, sugar beets are the most common feedstock for ethanol production. The consumption of sugar beets is anticipated to reach 7.45 million metric tonnes in 2021. With an expected consumption of 6.48 million metric tonnes in the same year, corn is the second most utilised feedstock.

Though sugar beets are the most used feedstock, the value is decreasing day by day relative to the previous year. For example, it was above 10k from 2012 to 2015 but decreased after 2015. In 2020, sugar beets consumption showed the lowest in the last decade. This study infers the reason for this was COVID-19. COVID-19 influenced both production and consumption of biofuel energy. The pandemic influence is not only for sugar beets but also applicable to other feedstocks. In 2021, it was found that EU fuel ethanol production raised to approximately 5.6 billion litres. The third most used feedstock is wheat. Still, there are some other feedstocks used in ethanol production. These are sugar beets, corn, wheat, rye, barley, triticale, and cellulosic biomass. However, the other feedstock used is much less than sugar beets, corn, and wheat.

Table 1. Fuel ethanol feedstock consumption in the EU

Year	Sugar beets	Corn	Wheat	Rye	Barley	Triticale	Cellulosic biomass
2015	10,010	5,218	3,661	712	414	1,031	200
2016	8,830	5,060	3,932	638	379	1,285	200
2017	8,292	5,065	5,197	507	383	720	160
2018	7,949	6,881	3,497	501	503	867	40
2019	8,264	7,066	2,855	373	327	874	40
2020	6,670	6,350	2,510	520	435	835	100
2021	7,450	6,480	2,635	520	450	1,035	200

Source: European Union: Biofuels Annual 2021 (in 1,000 metric tons)

Country-specific fuel ethanol consumption

Biofuel consumption is one of the alternative combustion methods for fossil fuel consumption. Biofuel consumption has relatively less impact on the environment. Globally, biofuel consumption is becoming more and more popular. Most developed countries attach great importance to replacing fossil fuels with biofuels. The EU is also one of the regions with the largest consumption of biofuels. The largest consumer of fuel ethanol in the European Union is Germany. According to *European Union Biofuels Annual*, the nation is projected to consume approximately 1.52 billion litres in 2021, a 9.4 per cent increase from the previous year. Comparatively, France, the second leading consumer of ethanol in the EU, was expected to consume 695 million litres in 2021. Compared to Germany, France consumes less than half of ethanol. The Netherlands is the third leading consumer of ethanol, with 445 litres in 2021, an almost 14% increase compared to 2020. Poland is the fourth leading consumer of ethanol, with 360 litres in 2021, an almost insignificant change compared to 2020 (356 litres). Spain is the fifth leading consumer of ethanol, with 195 litres in 2021, an almost insignificant change compared to 2020 (190 litres). Currently, biofuels' primary function is transportation. Bioethanol and biodiesel are the most important biofuels. In 2020, EU transportation biodiesel

consumption exceeded 13 million metric tonnes of oil equivalent. Biodiesel was by far the most utilised biofuel, with an approximate 80 per cent market share. The details of the country-specific biofuel consumption scenario are given in Figure 5.

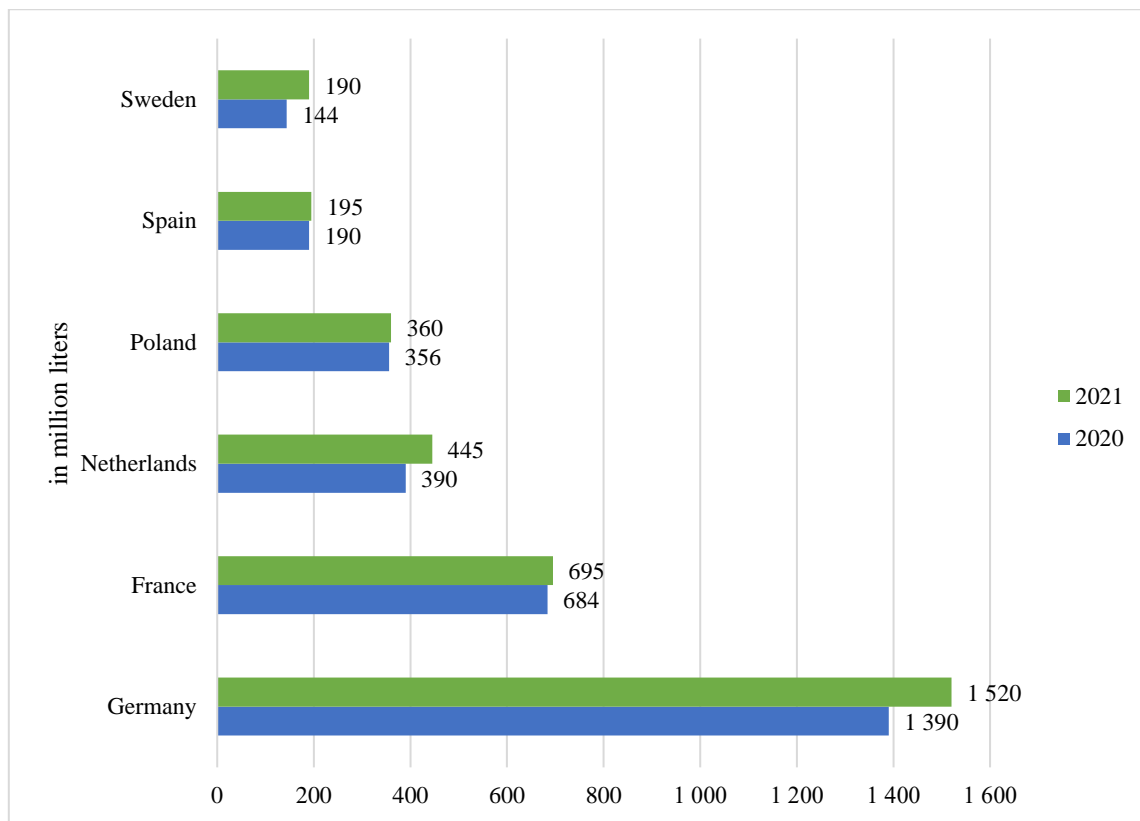


Figure 5. Country-specific fuel ethanol consumption (2020-2021)

Source: Authors illustration

Share most used renewable energy consumption

The most common type of renewable energy usage in the EU are biodiesel, bioethanol, renewable electricity, and biogas. With a share of 73.8%, biodiesel is by far the most popular renewable energy source among the 27 nations of the European Union (5). Biodiesel is a sustainable, biodegradable fuel made domestically from waste cooking oils, animal fats, vegetable oils, or used restaurant grease. Biodiesel differs from renewable diesel, sometimes called "green diesel" (ALLAMI et al., 2022; PINTO et al., 2005). According to the *RES Transport barometer*, bioethanol is the second most popular renewable energy source, which covers 13.90% of overall renewable energy usage. The third most popular renewable energy source is renewable electricity, which covers 10.50% of overall renewable energy usage. The fourth one is biogas, which made up less than 2% of the total, and bioethanol made up roughly 14%. The detail of the most used renewable energy is given in Figure 6.

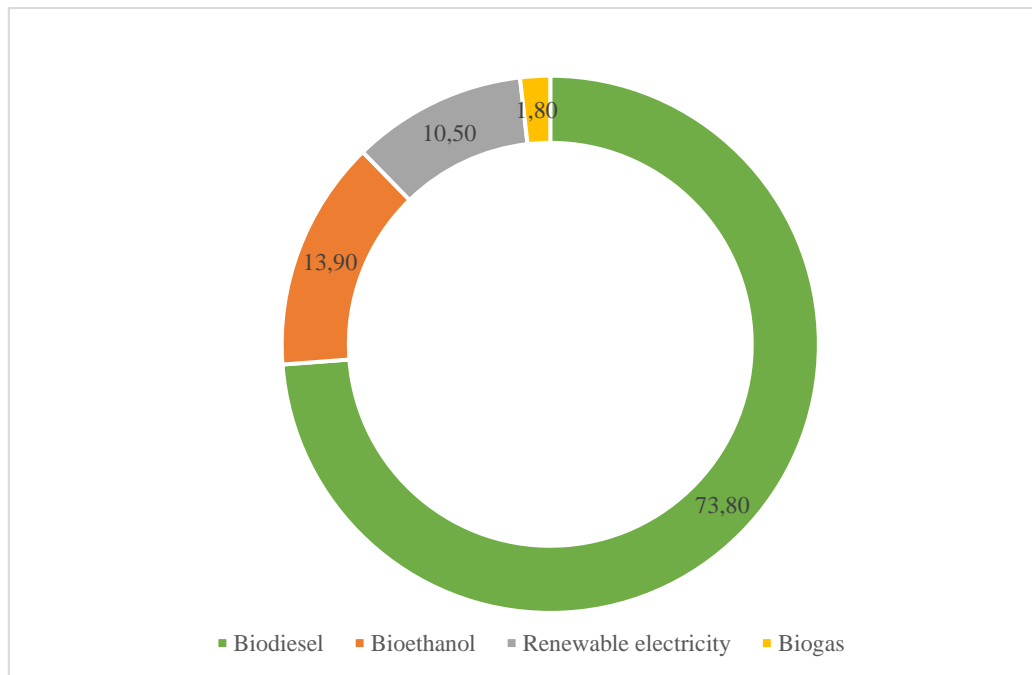


Figure 6. Share the most used renewable energy consumption (value in %, 2020)
Source: Authors illustration

Biofuel consumption for transport

The transportation sector is one of the main uses for biofuels. Because they are relatively energy dense (in contrast to electricity and batteries) and simple to transfer through the existing infrastructure with only slight modifications, they are highly suited for transportation (unlike hydrogen). Furthermore, because biofuels and petroleum-based fuels have many similarities, almost any modifications are necessary to make automobiles compatible with biofuels (6). The consumption of biofuels for transportation among European Union members has increased over time. According to *RES Barometer*, between 2015 and 2020, the total consumption of biodiesel increased by approximately 1577 thousand metric tonnes (15779 in 2020 – 14202 in 2015). In 2020, total biofuel consumption reached 15779 thousand metric tonnes, with biodiesel accounting for approximately 13012 thousand metric tonnes of oil equivalent, making it the most consumed biofuel throughout Europe. Besides the United Kingdom's exclusion from the EU in 2020, the decrease in biofuels could be directly attributed to the coronavirus pandemic. Since 2015, Germany's biodiesel consumption for transportation has steadily increased, reaching a peak of approximately 3.0 million tonnes of oil equivalent in 2020, representing the largest proportion of biofuels consumed. In 2020, the consumption of bioethanol and biogas as fuels increased slightly, reaching 701.6 and 76 kilotons of oil equivalent, respectively (7). In 2018, France's consumption of biofuels for transportation amounted to approximately 3.4 million metric tonnes of oil equivalent. Approximately 2.6 million metric tonnes of oil equivalent were produced in 2020, the record low for the period under consideration. Most of the biodiesel that was used in 2020 was converted into biodiesel, accounting for 79% of the total. This year's decline is directly attributable to the coronavirus pandemic (8). In 2020, Hungary consumed approximately 155.2 kilotons of oil equivalent to biodiesel for transportation. The consumption of bioethanol was less than that of biodiesel (9). The Italian biofuel consumption for transportation was considerably greater than bioethanol consumption. In 2020, the nation consumed 1.25 million metric tonnes of biodiesel equivalent and 19.6 thousand metric tonnes of bioethanol equivalent (10). In 2020, Spain consumed approximately

1.55 million metric tonnes of oil equivalent from biofuels. This decline of over 10% compared to the previous year is directly attributable to the coronavirus pandemic. During the period under consideration, biodiesel was by far the most widely used biofuel in Spain, accounting for nearly 94% of all biofuels consumed in 2020 (11). In 2019, the consumption of biofuels for transportation in the Netherlands reached 638.3 kilotons of oil equivalent, the highest level since 2015. Biodiesel consumption has always been significantly greater than bioethanol, and biogas consumption has always been the lowest among these three fuels. In 2020, the Netherlands consumed 301.4 kilotons of oil equivalent worth of biodiesel and 34.6 kilotons of oil equivalent worth of biogas fuel (12). In 2017, Bulgaria's consumption of biofuels for transportation peaked at 195.4 kilotons of oil equivalent. The numbers decreased by 48.4 kilotons of oil equivalent by 2020. The nation's biodiesel consumption was 120,5 kilotons of oil equivalent at the time. Compared to biodiesel, bioethanol consumption was significantly lower (13).

Biofuel and bioethanol are used not only for transportation; but also for other appellations such as biofuel for power generation, fuel cells by thermochemical reaction, fuel in cogeneration systems, and feedstock used in the chemicals industry. The detail of biofuels consumption for transport is given in Figure 7.

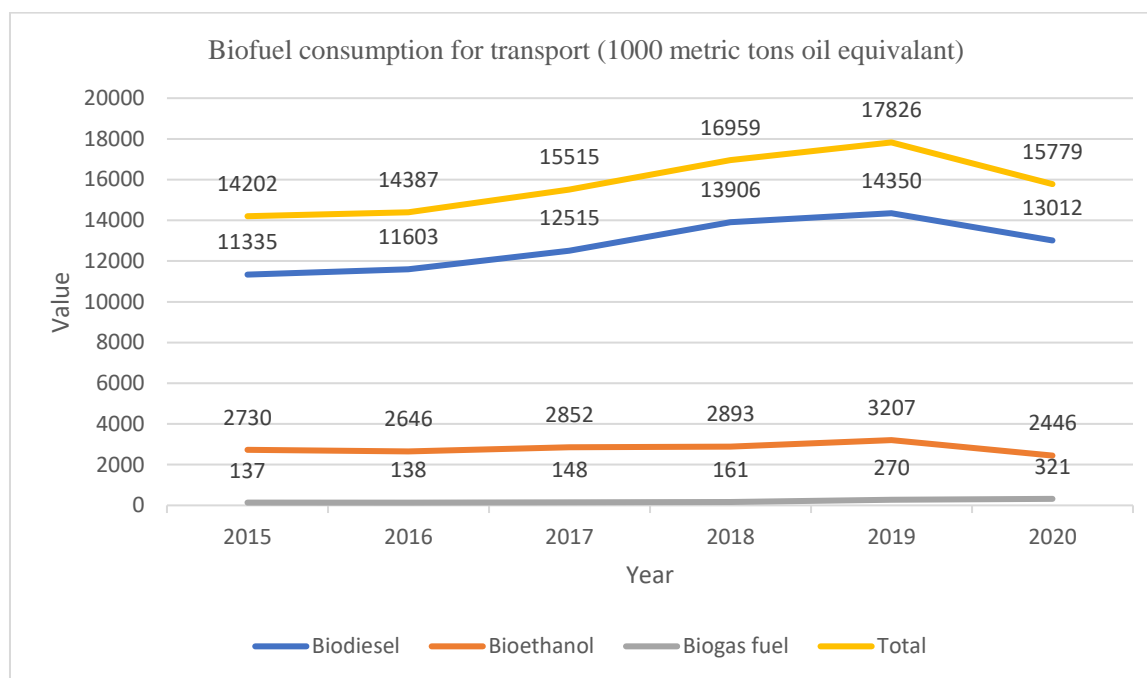


Figure 7. Biofuels consumption for transport (2015-2020)

Source: Author illustration

Discussion and conclusion

Biodiesel produced in Europe reduces the demand for fossil diesel imports, contributes significantly to the development bio-economy, reduces the demand for imported animal feed, and strengthens the rural economy. The development of biofuels in the EU is not so old. Particularly, biofuel development has taken place in the previous 15 years (starting from 2005 onward). However, this decade is the most significant era of biofuel development. Though we use the region EU, all countries do not contribute significantly when considering the EU as one economic zone.

In most cases, Germany, France, Netherlands, and Spain produce the highest quantity of biofuels in the EU. They are the leaders in biofuel production in this region. Due to COVID-19, there was a significant impact on the biofuel economy. The production of biofuels drastically reduced in 2020 and again started to rise in 2021. But still not significant. Even not only concerning biofuel production, also fuel ethanol production, France, Germany, the Netherlands, and Spain are the leaders. In this case, Hungary and Belgium have higher production quantities relative to other countries. In biofuel and fuel ethanol production cases, Sugar beets, corn, and wheat are the most dominant feedstock in the EU with significant quantities. Somehow, the leading countries produce larger quantities of biofuels and fuel ethanol and are the highest consumer of biofuel and fuel ethanol. Therefore, most countries produce to meet their own demand first. The most demanded renewable energies the countries use are biodiesel and bioethanol. However, biodiesel is the topmost used biofuel in the EU for different purposes. Among the different goals, the most significant is to use biodiesel and bioethanol for transportation, which consume the biggest portion of biodiesel in the EU.

This study also observes some benefits and shortcomings. Particularly, the most important benefit is the use of biofuel as an alternative source of energy source to reduce global warming. Biofuels significantly reduce carbon emissions and improve the quality of the environment. On the other hand, although biofuel manufacture uses gases that hasten the glasshouse effect, the fuel has negligible atmospheric CO₂ emissions. The goods' reliance on cultivation necessitates the use of intensive crops planted in deforested areas, particularly tropical forests. Additionally, intensive agriculture is one of the major water consumers and destroyers of biological diversity. The inputs required for biofuels drive the decline of food crops since they offer bigger gains for growers.

Finally, this study suggests the development of cost-effective technologies and supportive policies for biofuel production. In these cases, the most important issue is funding biofuel projects and investment in green technologies that produce more biofuels but emit less carbon. Also, other countries should emphasize their policies to increase biofuel production and focus on renewable energy usage to reduce the environmental impact.

Founding

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